

FORAGE PRODUCTION AND CHEMICAL COMPOSITION OF
TALL FESCUE (FESTUCA ARUNDINACEA SCHREB.)
AS INFLUENCED BY FERTILIZATION

By

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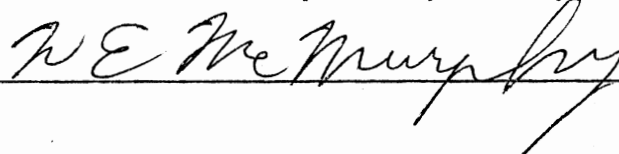
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Scope and Method of Study: A field study was initiated in February, 1975 in Osage County, near Wynona, Oklahoma. The vegetation of the area was a native hay meadow overseeded with tall fescue about three years previously. The soil was a Wynona silty clay loam that tested low in P and K. The objectives of the study were to evaluate the effect of rates of fertilizer P and K on seasonal forage production of tall fescue and native grass, its subsequent mineral composition in terms of percent N, P, and K in the plant tissue, and soil test values for pH, P, and K.

The experimental design of the study was a randomized complete block with 10 treatments in four replications. Nitrogen was applied at 112 kg/ha as ammonium nitrate. Three rates of P (0, 15, and 29 kg/ha) as concentrated superphosphate and three rates of K (0, 28, and 112 kg/ha) as muriate of potash were utilized. Omission of the check plot produced a 3 x 3 factorial arrangement of treatments in a randomized complete block design.

Findings and Conclusions: Spring forage production of tall fescue was increased by P fertilization starting the second year of the study and increased yields each year subsequently. Forage production was increased in only two years by K fertilization. Fertilization with P depressed the forage N concentration and increased the P concentration of the forage. Generally, fertilization with K had no effect on the N or P concentration of the forage. Potassium concentration of tall fescue was increased by K fertilization and was generally unaffected by P fertilization. Fall forage production of tall fescue was erratic, with only two harvests in six years. Native grass forage production was also erratic. Generally, P and K fertilization had no effect upon yields. Forage N concentration indicated that the tall fescue had utilized most of the N. Phosphorus concentration and K concentration of the native grass were generally increased by only P and K fertilization, respectively. The botanical composition of the native hay meadow was not different due to fertility treatments. The four major decreaser species, Andropogon gerardi, Schizachyrium scoparius, Sorghastrum nutans, and Panicum virgatum comprised 65% of the total vegetation. Soil test results indicated greater quantities of soil P and soil K due to fertilization with P and K respectively. Soil pH was not affected.

ADVISER'S APPROVAL





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CHAPTER I

INTRODUCTION

Tall fescue (Festuca arundinacea Schreb.) is one of the most important forage grasses in the United States (Buckner and Cowan, 1973). Because of its ability to grow over a wide range of soil and climatic conditions, it has been one of the most widely cultivated grasses for forage, turf, and conservation purposes since the 1940's.

Tall fescue is mainly limited to the eastern one-third of Oklahoma and grows on a wide variety of soils. It's primary use is for wintering of older cows with calves.

Adequate forage production is significantly related to the amount of fertilizer applied and the amount of fertilizer applied generally increases the subsequent mineral composition of the forage.

The effects of fertilization practices on the mineral composition of forages has been the subject of extensive research for over a century. Many early reviews have been written concerning the effect of soil fertility and its relation to plant and animal production (Beeson, 1945; Beeson, 1946; Webb et al., 1948; Thacker and Beeson, 1957; Ward, 1959) and will not be considered here.

The objectives of this investigation were to evaluate the effects of rates of fertilizer P and K on the quantity and quality of forage from a native hay meadow overseeded with tall fescue, and soil test values.

CHAPTER II

LITERATURE REVIEW

Fertilization practices are known to influence the quantity and quality of forages. Measurements of dry matter yield, plant concentrations of N, P, K, and other measurements have been used to determine the influence of various fertilization rates on the quality and quantity of forages. Fertilization effects on yields and subsequent concentrations of N, P, and K are areas in which much research with forages has been done.

Importance of Soil Fertility and Fertilization

Soil fertility is defined as the ability of the soil to supply nutrients to plants and is a major factor in forage production (Woodhouse and Griffith, 1973).

Applying fertilizers to maintain and improve soil fertility becomes necessary as soils are depleted of nutrients by crop removal, leaching and erosion, and as attempts are made to push yields higher and higher (Woodhouse and Griffith, 1973). This is a practice that becomes more vital as world population increases.

Woodhouse and Griffith (1973) have reviewed the fertilization of forages, and Epstein (1972) has reviewed the functions of N, P, and K in higher plants. These nutrients are essential elements for both plant and animal nutrition.

Nitrogen is considered the fourth most abundant element in plants, and is vital in both forage quality and yield. It is a major constituent of proteins, approximately 18%. Nitrogen is absorbed primarily as the nitrate ion, NO_3^- , then reduced and incorporated into organic compounds. The chlorophyll of green plants is a nitrogenous compound; thus N is essential for photosynthesis, growth, and reproduction.

Phosphorus is absorbed by plant roots primarily as the dihydrogen phosphate ion, H_2PO_4^- . The key role of phosphate in energy metabolism is the adenosine triphosphate, which is the universal "energy current" of all living cells. It is a key nutrient in both growth and cell division and tends to be concentrated in young actively growing tissues. Since these tissues are generally the most palatable and nutritious, high quality forage requires an adequate supply of P.

Potassium does not become an integral part of any particular plant constituent but is vital in many plant functions. It is absorbed by plants in the ionic form, K^+ . The principle role of K is that of an activator of numerous enzymes. It also plays roles in the formation of sugars and starches, the translocation of these within the plant, protein synthesis, stomatal action, and the neutralization of organic acids. Potassium is required in fairly large quantities by most forages. A total K concentration of 2 - 3% is common. Due to high levels of the cation in the nutrient medium, K also exhibits "luxury consumption" even to the extent of depressing the absorption of other cations.

Although each nutrient plays a different role, successful forage production requires adequate supplies of all the essential elements. Nitrogen is often the first limiting factor in the growth of forage

grasses, but the efficiency with which it can be utilized is very much dependent upon the presence of adequate quantities of all the others.

High quality legumes such as alfalfa (Medicago sativa L.) thrive only on soils well supplied with P, Ca, Mg, and K. Similarly, grasses such as timothy (Phleum pratense L.), orchardgrass (Dactylis glomerata L.), and tall fescue grow well only if there is ample N and adequate quantities of other essential nutrients.

Mineral Composition and Yield of Forages

According to Rhykerd and Noller (1973) the fertilization of grasses with N generally results in a greater carrying capacity and more live-stock production per hectare. Nitrogen fertilization increases both total N and N fractions and is important in that it influences forage quality and possibly animal health. Nitrogen fertilization reduces the percent dry matter and water-soluble carbohydrates and increases the crude protein concentration. This may cause an imbalance between protein and energy, especially in cool season grasses, and perhaps accounts for the low animal performance associated with the application of nitrogenous fertilizers.

The average dry matter and protein yield response per unit of fertilizer N declined as the N rate was increased on tall fescue (Hallock et al., 1965). Fescue failed to show a yield response beyond a 448 kg/ha N rate, of which 200 kg/ha were applied in three equal summer applications, due to a severe stand depletion. Excellent stands were maintained when a N rate of 224 kg/ha per year was utilized of which 90 kg/ha was applied in three equal summer applications. The rate of K fertilization was increased concurrently with N fertilization and K

concentration of the tall fescue increased, while that of P decreased. Hallock et al. (1973) surmised that tall fescue may tolerate high annual rates of N even in summer when N was applied frequently and in small increments. In this experiment crude protein and yields increased and stands improved from 17 weekly applications of 22.4 kg of N/ha during the summer with an initial pretreatment of 168 kg of N/ha in the spring. Annual rates of 834 and 1,120 kg/ha, of which 666 kg and 952 kg of N/ha were applied in the summer, caused severe stand reductions and reductions in crude protein concentration. Alexander and McCloud (1962) found that tall fescue receiving 403 kg of N/ha in three applications in April, June, and September caused a 25% stand reduction.

McKee et al. (1967) obtained highest yields of tall fescue with frequent defoliation when grass was 15 cm high, and N pretreatments were 22 kg of N/ha. Lowest yields were reported when 336 kg of N/ha applied as a pretreatment in the spring and tall fescue was not clipped until the flowering stage. These low yields were associated with reduced grass stands.

Fuller et al. (1971) reported increased yields from tall fescue with increasing rates of N through the rate of 717 kg/ha per year when P and K were adequate. A six fold increase in forage production was obtained with N fertilization. However, without P and K, forage production was lower. Phosphorus increased yields at moderate to high levels of N fertilization but had little effect on forage production at low levels. Maximum yields were obtained with 39 kg of P/ha. Applications of K also increased forage production whenever N and P were adequate. Maximum yields were obtained with 74 kg of K/ha. Application of N enhanced the crude protein concentration of the forage, however, when

production was increased by P and K with N held constant, crude protein decreased. This illustrated the well known inverse yield-protein phenomenon.

Ocumpaugh and Matches (1977) evaluated the autumn-winter yield and quality of tall fescue as affected by mid-summer and late summer defoliation. These researchers found that after the first week of below freezing temperatures in early November, growth ceased and harvestable dry matter started to decline. The average rate of decline was about 25 kg/ha per week. The K concentration of autumn grown fescue declined an average of 0.1 percentage unit per week. The low levels of K in the diet may reduce voluntary intake by ruminants. Recommendations at the conclusion of the experiment were for producers to utilize stock-piled tall fescue by the end of December in order to avoid dry matter losses and deficient levels of K.

The National Research Council (1976) suggested nutrient requirements of beef cattle. The following requirements were expressed as percent dry matter of diet: (1) a dry, pregnant 500 kg cow requires at least 0.94 N, 0.18 Ca and P, 0.60 K, and 0.04 Mg; (2) a lactating cow, 500 kg with average milking ability requires at least 1.47 N, 0.29 Ca and P, 0.80 K, and 0.18 Mg. Percent N was calculated by dividing the total crude protein requirement by 6.25. It should be noted that 0.20% Mg was considered a safe level in forages in the control of grass tetany (Kemp, 1960).

Raising N fertilizer levels from 50 to 200 kg/ha increased average crude protein concentration from 16.9 to 23.1% in tall fescue according to Hojjati et al. (1977). Nitrogen fertilization had an inconsistent effect on herbage P concentration. Highest P concentrations were

usually obtained two weeks after N fertilization. The effect of N on P concentration was most marked from 21 May to 2 July, and P concentration decreased as N was increased. Averaged across all treatments, the percentage P in tall fescue was 0.37 with a minimum value of 0.30. Increasing N from 50 to 200 kg/ha consistently increased herbage K concentration of fescue. Potassium concentration reached peak levels 2 - 3 weeks after N application and decreased thereafter. Averaged over all treatments K concentration for fescue was 3.20%; at the highest rate of N fertilization fescue removed more K (115 kg/ha) in the three week period of 9 April to 21 May than had been applied at the beginning of the season.

Powell et al. (1967) fertilized tall fescue throughout the fall and winter with N. If October applications were followed by monthly and bimonthly N applications of 2 kg/ha, then excellent foliage color was maintained throughout the winter. No measurable top growth occurred from December to March, but high N levels induced early and rapid spring growth. Lane et al. (1975) studied the relationship of plant color to yield and nutritive value of tall fescue within season. Color was significantly correlated with crude protein percentage, dry matter yield, and digestible dry matter yield.

Hunt (1973) observed that increasing the N rate on perennial ryegrass (Lolium perenne L.) increased the N concentration of the herbage and that the non-protein nitrogen rose significantly with each increment of N. Increased N application also resulted in higher concentrations of P and K, but these values decreased as the season progressed.

In further studies of N response, Hunt (1974) found that increasing levels of N fertilization significantly increased the P and K

concentrations in the primary growth and the P concentration of the first regrowth of perennial ryegrass. Both decreased significantly in the second regrowth.

Mortensen et al. (1964) found increased orchardgrass yield responses to N fertilization, and the removal of all elements was directly related to this fertilization. Nitrogen application influenced the uptake of K more than that of any other element except N. Generally, more K was removed by the grass receiving N fertilization than was returned by the annual application of 109 kg of K/ha. At the conclusion of the study the exchangeable K level in the soil was profoundly reduced at all depths by increasing N fertilization. Soil P levels in the 5 to 10 cm soil samples were definitely depressed by N fertilization.

Robinson et al. (1962) studied the effect of time, frequency, and rate of K fertilization on a Hagerstown silty clay loam over a six-year period. Potassium fertilization prolonged the stand of orchardgrass and increased the herbage yield. The time of application had a marked effect on the seasonal uptake of K. The herbage from plots receiving no K fertilization was low in K concentration with a definite trend toward a higher K concentration in the spring and a lower concentration in the summer and fall. Single, light applications of K in either fall or spring aggravated this trend. A single summer application largely overcame the tendency toward luxury consumption in the spring and starvation in the fall. This summer application was also relatively effective in maintaining a K concentration above 2.0% in plant tissue. Results with split applications were disappointing because too much of the K was applied in the spring. Where split applications are needed to provide an adequate supply of K throughout the season, a substantial part

of the total should probably be applied in the summer.

Templeton et al. (1969) used sand-soil mediums to test young orchardgrass growth at differing rates of N and P fertilization. At the third harvest a striking N x P interaction was evident with respect to dry weight of shoot, number of leaves on the primary shoot, and total length of leaf blades. This pattern of interaction was similar for each of the measurements and at each of the harvests. No response to N was obtained unless more than 11 kg/ha of P was applied. Response to P was not restricted by N level, however, until the P rate was increased to 44 kg/ha. Thus, in the untreated sand-soil growth medium, the supply of P was more limiting to growth and development than was that of N.

Black (1968) reported that N alone increased forage yields of crested wheatgrass (Agropyron desertorum) about as much as N plus P despite the extremely low P content throughout the soil profile. However, P concentration of the forage at full bloom was significantly increased by applications of P fertilizer.

Grass hay production in response to N from a sward consisting of a mixture of brome grass (Bromus inermis Leyss.), timothy, orchardgrass, bluegrass (Poa pratense L.), and occasional plants of red clover (Trifolium pratense L.) was restricted in the absence of applied P (Ludwick and Rumburg, 1976). In general, yields increased to the highest rate of applied P, with each rate of P, 20, 39, and 59 kg of P/ha, producing a significant yield increase. Fall applied N-P combinations were superior to the same combinations applied in the spring. Nitrogen concentrations were significantly affected only by N rates, and P concentrations increased with P rates and decreased with N rates. Nitrogen uptake was significantly influenced by rates of N, P, and time

of application. The larger uptakes were associated with the fall applied higher rates of N and P, which were the highest yielding treatments. Phosphorus followed the same pattern. Ludwick and Rumburg concluded that timing of fertilization for grass hay usually revolved around N. In this context, most agronomists agree it is more desirable to apply N fertilizers in the spring just prior to the initiation of spring growth than in the fall where it must "over-winter" and be subjected to leaching and denitrification losses. However, on soils deficient in P, the data from this study suggested that P applied in the spring could cause yield reductions. The benefit from fall fertilization with P seemed to result from additional time for the dissolution of P granules and movement of P into the soil to be available for the onset of spring growth.

Nitrogen increased yields, while K increased yield significantly only at the third harvest and at the zero N level of the first harvest in orchardgrass (Griffith et al., 1964). Application of K significantly increased the K concentration in the leaf tissue and N fertilization emphasized a K deficiency, presumably due to excess K removal.

Kresge and Younts (1963) found the best recovery of N, P, and K by orchardgrass at the highest yielding treatment, an annual application of 224 kg of N/ha and 93 kg of K/ha. They determined that a rate of 168 to 224 kg of N/ha may have been the optimum. A 2.4 to 1 N to K ratio was the best of all ratios tested regardless of the rate of N applied. However, the amount of K removed by the plant at this ratio was often double that which was applied. A lower ratio of 1.8 to 1 of applied N to K should be considered when the soil has a lower K supplying ability. The critical K concentration of orchardgrass forage is the minimum K

concentration required for maximum yield and was higher when higher rates of N were used. This percent K was 2.15 for 56 and 112 kg of N and 2.68 for 224 and 448 kg of N per hectare.

Yields of 'Alta' tall fescue were increased markedly in the first two cuttings but not in the third and fourth cuttings with each increment of 10-10-10 fertilizer applied (Duell, 1960). Mineral composition and protein concentration increased similarly with each increment of fertilizer. A more positive relationship existed between fertilization and nutrients in the plant material of the first cutting than in later cuttings.

In a subsequent experiment using the same fescue plots, Duell (1965) found the highest yield with an annual rate of 2240 kg of fertilizer as 10-4.4-8.3 in two applications. Fertilization with P and K enhanced the concentration of P and K within the plant tissues over those plots not fertilized with P and K.

Phosphorus concentration in tall fescue in April (Fleming and Murphy, 1968) was above 0.6% and steadily declined until July to about 0.3%. From late July until late August P concentration increased, then varied from 0.5 to 0.4% from September through December. Potassium levels of the fescue fluctuated between 3.5 and 4.7% from late April to early October. After October the level declined and in December the grass contained 2.5% K.

The highest K concentration in tall fescue was found in March and April (Hannaway and Reynolds, 1976). Phosphorus concentration was markedly affected by season, with the highest concentration occurring in the summer months. The Mg concentration was significantly depressed by K fertilization from November through April, with values below the

0.20% Mg from December through May. Hannaway and Reynolds suggest that K fertilization, if required, should follow the grass tetany period to reduce possible danger to animals grazing the forage produced.

Kentucky bluegrass had a positive yield response to applied N at all levels of P and K (Walker et al., 1963). Response to applied P was positive at all levels of N and K, and there was a small response to applied K at most levels of N and P. Increasing the rate of applied N, P, and K increased the concentration of N, P, and K, in the bluegrass (Walker and Pesek, 1963).

Reid and Jung (1965) found that N fertilization increased the K concentration of tall fescue in the first cutting and regrowth. Potassium fertilization alone had little effect on K concentration of the forage. Phosphorus fertilization increased the P concentration in plant tissue in the first cutting, but not in the regrowth. As a result of N fertilization, crude protein concentration increased in both cuttings of fescue. Intake trials with sheep revealed no significant differences due to fertilizer treatment from either cutting of tall fescue hay. In palatability trials, sheep had a primary preference for the fescue hay fertilized only with the P and a secondary preference for the fescue hay fertilized with 56 kg of N/ha. Forage intake from these preferred treatments were significantly higher than intake of any of the other hays. It should be noted however, that selection behavior of sheep on dried forage under stall-feeding conditions may be different from that of animals grazing fresh herbage. In this experiment, fertilizer treatment did influence the levels of P and K in the hays, but there appeared to be no consistent relationship between mineral composition and palatability.

Reid et al. (1970) noted that application of high levels of N increased K concentration in tall fescue when K in the soil was not a limiting factor. Increasing levels of N markedly increased the concentrations of K in the fescue over that in either the unfertilized fescue or the fescue treated with K or P alone. Tall fescue K uptake had little effect from the application of a high level of K fertilizer. There was a tendency of increasing levels of N to depress the plant concentration of P, but this was not noted in the first cutting of fescue. The highest concentration of P was found in that fescue fertilized only with superphosphate.

Sabbe and Hileman (1974) found that P concentration decreased with age in tall fescue while Mg increased. As soil moisture decreased, N and K in fescue decreased. Correlations of Mg with K were always negative, indicating a decrease in plant Mg as K increased.

Balasko (1974) found summer, winter and annual yields of tall fescue fertilized with N were two to three times greater than fescue not fertilized with N. Summer yields from fescue receiving the NK and NPK treatments were usually significantly higher than those from fescue receiving the N and NP treatments. Winter yields were reduced by 10% when harvest was delayed from December to January. Nitrogen fertilization increased N concentrations of the fescue, therefore increasing the crude protein equivalent. Phosphorus concentration of winter forage was generally around 0.20%. Phosphorus fertilization significantly increased forage P concentrations at both levels of N. Nitrogen fertilization aided in maintaining viability of winter forage and decreased the amount of loss of P from December to January. Potassium fertilization greatly increased the K concentration of winter forage at

both levels of N. The Mg concentration of forage harvested in winter was increased by N fertilization and was reduced by K fertilization. Concentrations of Mg in all forage harvested in the winter were usually below the value of 0.20%.

Summary

The literature indicated that N fertilization increased quantity and quality of tall fescue, but high rates could reduce stands. Research has shown that high infrequent rates of applied N during the summer will cause these reduced stands, but lower more frequent applications will help avoid these harmful effects. Increases in N concentration and the crude protein equivalent have also been noted.

Phosphorus concentration of tall fescue was variable. In some instances reports indicate that N fertilization increased the P concentration of the herbage, while in others it was reduced. It has been reported that response to N was restricted in the absence of P. Yields have been increased by P fertilization in some cases and unchanged in others. Phosphorus concentration may decrease with plant maturity.

Potassium concentration of tall fescue was increased by N fertilization but usually not with K fertilization alone.

CHAPTER III

MATERIALS AND METHODS

A field study was initiated in February, 1975, in Osage County, near Wynona, Oklahoma. This location is in the very western edge of the general area of adaptation of tall fescue (Burns and Chamblee, 1979). The vegetation was a native hay meadow overseeded with tall fescue about three years previously.

Soil testing revealed that the soil was deficient in P and K. As a result of these findings this study was initiated. The soil was a Wynona silty clay loam (fine-silty, mixed, thermic Cumulic Haplaquoll).

The experimental design of the study was a randomized complete block with 10 treatments in four replications. Deletion of the check plot, (0-0-0), produced a 3 x 3 factorial arrangement of PK treatments in a randomized complete block design. Individual plots measured 3.1 x 6.1 m.

Nitrogen was applied at an annual rate of 112 kg/ha as ammonium nitrate (34-0-0) on all plots except the check. The N was applied in two applications, one in February of 45 kg of N/ha and one in August of 67 kg of N/ha. Three rates of P (0, 15, and 29 kg/ha) as concentrated superphosphate (0-46-0) and three rates of K (0, 28, and 112 kg/ha) as muriate of potash (0-0-60) were utilized. Phosphorus and K were applied in February and August of 1975, then only in August of each succeeding year. All fertilizer applications were broadcast with a 0.9 m Gandy

fertilizer spreader.

Forage was clipped seasonally, in late May or early June, mid-August and mid-December. December yields were poor; therefore, harvests were taken in only two years (1975 and 1977). May harvests were taken for six years and August harvests for five.

Forage production was harvested with a flail mower from a 0.9 x 6.1 m area clipping at 5 cm height. A representative moisture sample from each plot was oven dried at 60 C and production results are reported as oven dried kilograms per hectare.

Soil samples from each plot were taken from two depths, 0-15 cm and 15-30 cm, in 1975 before the treatments were applied. Each subsequent year soil samples were taken from the 0-15 cm depth. At the conclusion of the study, soil samples were taken in November of 1980 at a depth of 0-15 cm and 15-30 cm.

Botanical composition of the native hay meadow was determined on 3 October 1980 using a point frame, reading 200 points per plot (Levy and Madden, 1933).

Laboratory Procedures

Dried forage samples were ground in a Wiley mill to pass a 2 mm screen. The ground samples were analyzed for N, P, and K.

The Kjeldahl method was used for N determination of the forage samples. Plant samples were subjected to a perchloric acid digestion then P was determined colorimetrically by the ammonium vanadate reaction. Potassium was determined by an atomic absorption spectrophotometer (E. A. Hanlon, personal communication).

Soil samples taken from each plot were analyzed for P, K, and pH.

Available P was extracted by the Bray-1 extractant as described by Olsen and Dean (1965) with a modification utilizing a 20:1 solution to soil ratio. Available soil K was extracted with ammonium acetate and determined with an atomic absorption spectrophotometer (E. A. Hanlon, personal communication). Soil pH was determined on a 1:1 soil to water paste as outlined by Jackson (1958) modified utilizing 15 g of soil. If the pH reading was less than 6.5, then 30 ml of SMP Buffer solution was added as proposed by Shoemaker et al. (1961) and pH was read again.

Statistical Analyses

The data collected each year were subjected to an Analysis of Variance (Steel and Torrie, 1960) and treatment means were compared using Fisher's Protected Least Significant Difference method as outlined by Chew (1977). Then the data from the check plots was omitted to analyse as a PK factorial to test for the main effects of P and K and the PK interaction.

CHAPTER IV

RESULTS AND DISCUSSION

Tall Fescue - Yield

Spring Forage Production

Dry matter yields of tall fescue for 1975 through 1980 are presented in Table 1. Yields ranged from a low of 1108 kg/ha for the unfertilized plots in 1978 to a high of 6141 kg/ha for the highest rates of P and K in 1980.

Each year of the study application of 112 kg of N/ha increased yields over those of the check plot regardless of rates of P and K. No significant PK interactions were noted in any year; therefore only main effects (P and K) will be discussed for each year.

In the first year of the study, fertilizer treatment significantly increased yields of tall fescue and this was primarily attributed to treatment combinations with N since no significant effects for P and K were noted. Highest yields were associated with plots fertilized with 29 kg of P and 28 kg of K/ha and yields were significantly higher than those yields from plots receiving 0 kg of P and 112 kg of K/ha or those receiving 15 kg of P and 0 kg of K or 28 kg of K/ha. By the second year there was a significant increase in yields due to P fertilization. There was an increase in yield associated with each increment of P and the 3331 kg/ha average yield at the highest rate of applied P (29 kg/ha)

Table 1. Forage production of tall fescue harvested in late May or early June averaged over four replications.

Fertilizer			Year						6 Year
N	P	K	1975	1976	1977	1978	1979	1980	Mean
kg/ha									
0	0	0	1504	1289	1262	1108	2183	2004	1558
112	0	0	2616	2683	2878	2098	3336	4098	2952
112	0	28	2683	2639	2866	2301	3246	3714	2908
112	0	112	2271	2606	3675	2643	3604	4810	3268
112	15	0	2397	2907	3685	3315	4110	5613	3671
112	15	28	2470	2602	3002	3533	3661	5787	3509
112	15	112	2700	3547	3826	3799	3685	5757	3886
112	29	0	2506	3305	3084	3218	3950	5621	3614
112	29	28	3139	3214	3354	3761	3734	5997	3866
112	29	112	2777	3474	4053	4129	4478	6141	4175
LSD	.05		546	731	524	490	928	745	378
Phosphorus Mean									
	0		2523	2643	3140	2347	3395	4207	3043
	15		2522	3019	3505	3549	3819	5719	3689
	29		2807	3331	3497	3702	4054	5569	3885
LSD	.05		NS	438	308	274	377	450	178
Potassium Mean									
		0	2506	2965	3216	2877	3799	5110	3412
		28	2764	2818	3074	3198	3547	5166	3428
		112	2582	3209	3851	3524	3923	5569	3776
LSD	.05		NS	NS	308	274	NS	NS	178

was significantly greater than the average 2643 kg/ha yield at the 0 kg/ha rate of applied P. There was no significant effect on yield associated with K application in 1976.

Both P and K fertilization significantly influenced yields in 1977 and 1978. In both years the 15 kg and 29 kg/ha of P rate produced significantly greater yields than did those of the 0 kg/ha rate of applied P when averaged over all K rates. Averaged over all P rates, the highest rate of applied K (112 kg/ha) produced a significant increase in yield over those of the 0 kg or 28 kg/ha rates of K in 1977 and 1978.

Phosphorus increased yields in 1979 and 1980 but no K effects were noted. In both years the 15 kg and 29 kg/ha rates of applied P significantly increased yields over those of the 0 kg rate of applied P.

Spring forage production was quite variable over the course of the study. In general the yields from plots receiving either or both P and K increased during the course of the study. Also P fertilization had a greater effect than K on this increase.

Forage production in the six year mean was significantly increased by P and K fertilization. The highest rate of applied P and K, 29 and 112 kg/ha respectively, gave the highest yields. There was no difference between the 0 kg and 15 kg/ha rate of P fertilization or between the 0 kg and 28 kg/ha rate of K fertilization.

Fall Forage Production

Dry matter yields for fall harvested tall fescue are presented in Table 2. Forage production from fall harvests of tall fescue were very erratic. Only in 1975 and 1977 was there sufficient standing forage to

Table 2. Forage production of tall fescue harvested in December averaged over four replications.

Fertilizer			Year	
N	P	K	1975	1977
kg/ha				
0	0	0	520	1407
112	0	0	966	2456
112	0	28	923	2332
112	0	112	811	3072
112	15	0	984	2754
112	15	28	661	2604
112	15	112	785	2899
112	29	0	817	3376
112	29	28	1031	2986
112	29	112	955	3110
LSD .05			NS	569
Phosphorus Mean				
	0		900	2620
	15		810	2752
	29		934	3158
LSD .05			NS	348
Potassium Mean				
		0	922	2862
		28	871	2640
		112	850	3027
LSD .05			NS	NS

harvest.

Neither P nor K had an effect on yield in 1975. In 1977, P was found to significantly increase forage production. The highest rate of applied P (29 kg/ha) significantly increased yields of fall harvested tall fescue. The 0 kg and 15 kg/ha rates of applied P were not significantly different. Potassium had no effect on yield.

Tall Fescue - Nutrient Concentration

Spring Forage Nitrogen Concentration

Nitrogen concentration of spring harvested tall fescue forage varied considerably throughout the study and year to year variations were greater than treatment effects (Table 3). No significant PK interactions were noted in any year so main effects (P and K) will be discussed for each year. There were no significant differences in main effects for 1976 and 1978.

The first year of the study (1975) P fertilization had no effect on N concentration of tall fescue. Potassium fertilization increased the N concentration from 1.55% at the 0 kg rate to 1.73% at the 112 kg/ha rate. There was no difference between the 0 kg rate and 28 kg/ha rate.

In 1977, both P and K had an effect on N concentration. The main effects of P were to decrease the N concentration. The N concentration of tall fescue was reduced from 1.67% at the 0 kg rate to 1.48% at the 29 kg/ha rate. There was not a significant difference between the 15 kg and 29 kg/ha rate of P in terms of N concentration. The N concentration of tall fescue was increased by the highest rate of applied K

Table 3. Nitrogen concentration of tall fescue harvested in late May or early June averaged over four replications.

Fertilizer			Year						6 Year Mean
N	P	K	1975	1976	1977	1978	1979	1980	
kg/ha			%						
0	0	0	1.70	1.43	1.28	1.33	1.41	0.65	1.30
112	0	0	1.66	1.44	1.57	1.72	1.81	1.03	1.54
112	0	28	1.54	1.46	1.65	1.62	1.71	0.90	1.48
112	0	112	1.79	1.48	1.81	1.51	1.75	0.90	1.54
112	15	0	1.42	1.40	1.39	1.44	1.50	0.83	1.33
112	15	28	1.52	1.49	1.42	1.55	1.59	0.73	1.38
112	15	112	1.72	1.58	1.47	1.53	1.45	0.85	1.43
112	29	0	1.59	1.57	1.42	1.54	1.44	0.83	1.40
112	29	28	1.54	1.38	1.36	1.53	1.58	0.78	1.36
112	29	112	1.68	1.29	1.67	1.40	1.34	0.88	1.37
LSD	.05		NS	NS	0.17	0.20	0.22	0.16	0.10
Phosphorus Mean									
	0		1.66	1.46	1.67	1.62	1.76	0.94	1.52
	15		1.55	1.49	1.43	1.51	1.51	0.80	1.38
	29		1.60	1.41	1.48	1.49	1.45	0.83	1.38
LSD	.05		NS	NS	0.10	NS	0.13	0.10	0.06
Potassium Mean									
	0		1.55	1.47	1.46	1.57	1.58	0.89	1.42
	28		1.53	1.44	1.48	1.57	1.63	0.80	1.41
	112		1.73	1.45	1.65	1.48	1.51	0.88	1.45
LSD	.05		0.13	NS	0.10	NS	NS	NS	NS

(112 kg/ha) beyond that N concentration of tall fescue receiving the 0 kg or 28 kg/ha rates of K. No differences occurred between the 0 kg and 28 kg/ha rates.

Phosphorus fertilization in 1979 gave a significant decrease in N concentration of tall fescue. Potassium fertilization had no effect on N concentration. Each rate of applied P caused a reduction in N concentration of tall fescue and the 15 kg and 29 kg/ha rates of P were not different, but did decrease the N concentration below that observed for the 0 kg/ha rate.

The last year of the study (1980) P fertilization decreased the N concentrations of tall fescue. Potassium had no effect. The N concentration of tall fescue was significantly reduced by the 15 kg and 29 kg/ha rates of P below that N concentration of tall fescue receiving 0 kg/ha of P.

The N concentration of the six year mean was significantly depressed by P fertilization and was not affected by K fertilization. The 15 kg and 29 kg/ha rates of applied P reduced the N concentration below that of forage receiving 0 kg/ha rate of P.

Observed values for the N concentration were usually near the NRC requirement of 1.47% N for a lactating beef cow (National Research Council, 1976). All but the N concentrations of 1980 were above the NRC requirements of 0.94% N for a dry, pregnant beef cow.

Fall Forage Nitrogen Concentration

Nitrogen concentrations of fall harvested tall fescue (Table 4) were comparable to the N concentrations in the spring forage. There were no PK interactions or K effects. There was however, a significant

Table 4. Nitrogen concentration of tall fescue harvested in December averaged over four replications.

Fertilizer			Year	
N	P	K	1975	1977
kg/ha			%	
0	0	0	1.20	0.82
112	0	0	1.74	1.25
112	0	28	1.69	1.22
112	0	112	1.67	1.36
112	15	0	1.80	1.22
112	15	28	1.72	1.21
112	15	112	1.73	1.17
112	29	0	1.90	1.28
112	29	28	1.80	1.25
112	29	112	1.78	1.30
LSD	.05		0.18	0.13
Phosphorus Mean				
	0		1.70	1.28
	15		1.75	1.20
	29		1.83	1.28
LSD	.05		0.10	NS
Potassium Mean				
		0	1.81	1.25
		28	1.73	1.23
		112	1.73	1.27
LSD	.05		NS	NS

reduction in N concentration in 1975 by the 15 kg and 29 kg/ha rate of applied P below that of the 0 kg/ha rate of P.

Although neither of the main effects (P and K) had a significant effect on the N concentration in 1977, there was still a significant effect associated with the N fertilization. Fertilization with N increased the N concentration above that of the check plot regardless of rates of P and K. The N concentration of tall fescue fertilized with 0 kg of P and 112 kg of K/ha was the highest and was significantly higher in N concentration of tall fescue fertilized with 0 kg of P or 15 kg of P and 0 kg of K or 28 kg of K/ha in all PK combinations and forage fertilized with 15 kg of P and 112 kg of K/ha.

In 1975 all values observed were above the 1.47% N recommended by the NRC for a lactating beef cow with the exception of the check plot which was 1.20% N (National Research Council, 1976). In 1977 all values observed were above the 0.94% N recommended for a dry, pregnant beef cow with the exception of the check plot which was 0.82% N. All observed values for 1977 were below the NRC requirement of 1.47% N for a lactating beef cow.

Spring Forage Phosphorus Concentration

Phosphorus concentrations of spring harvested tall fescue for 1975 through 1980 are presented in Table 5. No significant PK interactions were noted in any year so main effects (P and K) will be discussed for each year.

In 1975, P fertilization increased the P concentration of tall fescue from 0.16% at the 0 kg rate to 0.21% at the 29 kg/ha rate. No differences were found between the 0 kg and 15 kg/ha rates of applied P.

Table 5. Phosphorus concentration of tall fescue harvested in late May or early June averaged over four replications.

Fertilizer			Year						6 Year Mean
N	P	K	1975	1976	1977	1978	1979	1980	
kg/ha			%						
0	0	0	0.19	0.14	0.11	0.19	0.15	0.12	0.15
112	0	0	0.16	0.10	0.12	0.14	0.18	0.07	0.13
112	0	28	0.15	0.10	0.10	0.13	0.14	0.07	0.11
112	0	112	0.15	0.10	0.14	0.15	0.14	0.07	0.12
112	15	0	0.19	0.14	0.16	0.22	0.16	0.13	0.16
112	15	28	0.19	0.14	0.15	0.21	0.17	0.15	0.17
112	15	112	0.18	0.14	0.17	0.24	0.18	0.16	0.18
112	29	0	0.20	0.18	0.16	0.27	0.21	0.19	0.20
112	29	28	0.21	0.18	0.17	0.24	0.21	0.18	0.20
112	29	112	0.22	0.17	0.21	0.28	0.21	0.19	0.21
LSD	.05		0.03	0.02	0.05	0.04	NS	0.06	0.02
Phosphorus Mean									
	0		0.16	0.10	0.12	0.14	0.15	0.07	0.12
	15		0.18	0.14	0.16	0.22	0.17	0.15	0.17
	29		0.21	0.18	0.18	0.26	0.21	0.18	0.20
LSD	.05		0.01	0.01	0.03	0.02	0.03	0.03	0.01
Potassium Mean									
		0	0.18	0.14	0.15	0.21	0.18	0.13	0.16
		28	0.18	0.14	0.14	0.19	0.17	0.13	0.16
		112	0.18	0.13	0.17	0.22	0.17	0.14	0.17
LSD	.05		NS	NS	NS	0.02	NS	NS	NS

Also K fertilization had no effect on P concentration in the forage.

The second year of the study (1976), P concentration increased to the highest rate of applied P (29 kg/ha) and each additional P increment produced a significant increase in P concentration of tall fescue.

Potassium fertilization had no effect.

In 1977 the P concentration of tall fescue was increased by P fertilization and was not affected by K fertilization. The P concentration increased from 0.12% at the 0 kg rate to 0.18% at the 29 kg/ha rate.

There was no difference between the 15 kg/ha or 29 kg/ha rate.

Both P and K fertilization had no effect on P concentration in 1978. Phosphorus concentration increased to the highest rate of applied P (29 kg/ha) and each additional increment produced a significant P concentration increase. Potassium fertilization at the 112 kg/ha rate increased the P concentration above that of the 0 kg or 28 kg/ha rates of applied K. No differences were noted between the 0 kg and 28 kg/ha rates of applied K.

In 1979 P fertilization alone increased the P concentration of tall fescue. The P concentration of tall fescue was increased from 0.15% at the 0 kg rate to 0.21% at the 29 kg/ha rate with no differences in P concentration between the 0 kg or 15 kg/ha rates of P.

The last year of the study (1980) P fertilization alone had a significant effect on the P concentration of tall fescue. The P concentration increased from 0.07% at the 0 kg rate to 0.18% at the 29 kg/ha rate. Phosphorus concentration was not different between the 15 kg or the 29 kg/ha rates of applied P.

Phosphorus concentration of the six year mean was increased with each increment of P fertilization with each additional P increment

producing a significant increase in P concentration of tall fescue. Potassium fertilization had no effect on P concentration in the six year mean.

All observations for P concentration were below the NRC requirement of 0.29% P for a lactating beef cow (National Research Council, 1976). Many of the observations were below the 0.18% P requirement for a dry, pregnant beef cow.

Fall Forage Phosphorus Concentration

The P concentrations of fall harvested tall fescue (Table 6) were very similar to the results with spring forage. Phosphorus concentration was consistently increased by P fertilizer and K fertilizer had no effects. There were no significant PK interactions. In both years of fall harvested tall fescue each additional increment of P fertilizer produced an increase in P concentration.

Observed values for P concentration in 1975 and 1977 at the 0 kg and 15 kg/ha rates of P, regardless of K rates were below the NRC requirement of 0.18% P for a dry, pregnant beef cow (National Research Council, 1976). Phosphorus concentrations associated with the 29 kg/ha rate and all rates of K were either very near or exceeded the NRC requirement of 0.18% P for a dry, pregnant beef cow. None of the values for either 1975 or 1977 were near the 0.29% P NRC requirement for a lactating beef cow.

Spring Forage Potassium Concentration

Potassium concentrations for spring harvested tall fescue in 1975 through 1980 are presented in Table 7. There was only one significant

Table 6. Phosphorus concentration of tall fescue harvested in December averaged over four replications.

Fertilizer			Year	
N	P	K	1975	1977
kg/ha			%	
0	0	0	0.10	0.08
112	0	0	0.10	0.11
112	0	28	0.11	0.08
112	0	112	0.10	0.11
112	15	0	0.15	0.15
115	15	28	0.14	0.15
112	15	112	0.15	0.16
112	29	0	0.19	0.20
112	29	28	0.17	0.20
112	29	112	0.17	0.19
LSD	.05		0.02	0.03
Phosphorus Mean				
	0		0.10	0.10
	15		0.14	0.15
	29		0.18	0.20
LSD	.05		0.01	0.02
Potassium Mean				
		0	0.15	0.15
		28	0.14	0.14
		112	0.14	0.15
LSD	.05		NS	NS

Table 7. Potassium concentration of tall fescue harvested in late May or early June averaged over four replications.

Fertilizer			Year						6 Year
N	P	K	1975	1976	1977	1978	1979	1980	Mean
kg/ha			%						
0	0	0	1.46	1.20	0.86	1.66	1.26	1.12	1.26
112	0	0	1.60	1.23	0.94	1.26	1.38	0.83	1.21
112	0	28	1.65	1.18	1.02	1.26	1.47	0.98	1.26
112	0	112	2.04	1.49	1.29	1.83	2.00	1.15	1.63
112	15	0	1.54	1.16	0.92	1.07	1.58	1.02	1.21
112	15	28	1.84	1.35	1.09	1.46	1.52	0.98	1.37
112	15	112	1.97	1.71	1.22	2.09	1.95	1.23	1.69
112	29	0	1.62	1.29	0.84	1.11	1.29	0.90	1.18
112	29	28	1.63	1.27	1.00	1.21	1.36	0.91	1.23
112	29	112	2.09	1.47	1.21	2.13	2.09	1.07	1.68
LSD	.05		0.29	0.26	0.15	0.29	NS	0.22	0.17
Phosphorus Mean									
	0		1.76	1.30	1.08	1.45	1.62	0.99	1.37
	15		1.78	1.40	1.08	1.54	1.68	1.08	1.43
	29		1.78	1.34	1.02	1.48	1.58	0.96	1.36
LSD	.05		NS	NS	NS	NS	NS	NS	NS
Potassium Mean									
	0		1.59	1.23	0.90	1.14	1.42	0.92	1.20
	28		1.71	1.26	1.03	1.31	1.45	0.95	1.28
	112		2.03	1.55	1.24	2.01	2.02	1.15	1.67
LSD	.05		0.17	0.16	0.09	0.15	0.40	0.13	0.10

PK interaction noted, in 1978. Potassium concentrations of spring harvested tall fescue were not influenced by the main effects of P. Discussion of these years will be based upon the main effects of K.

In the first two years of the study (1975 and 1976) the highest rate of applied K (112 kg/ha) increased the K concentration of tall fescue above that fescue receiving the 0 kg or 28 kg/ha rates of K. In 1977 each additional K increment produced a significant increase in K concentration.

In 1978 a significant PK interaction was observed. At the highest rate of applied K (112 kg/ha) each additional P increment produced an increase in K concentration; however, this did not occur at the lower K fertility levels. The K concentrations of tall fescue fertilized with 112 kg/ha of K, at all three rates of P, were significantly higher than any other PK combination utilized. In the last two years of the study (1979 and 1980) the K concentration was significantly increased by the 112 kg/ha rate of K. The 28 kg/ha rate of K did not produce an increase in the K concentration over that tall fescue receiving 0 kg/ha of K.

The six year mean of K concentration was found to be significantly increased by K fertilization with the 112 kg/ha rate of K having the greatest effect. No differences were found between the 0 kg and 28 kg/ha rates of K.

Observed values for the K concentration of spring harvested tall fescue from 1975 through 1980 were well above the 0.60% K recommended by the NRC for a dry, pregnant beef cow (National Research Council, 1976). Three of the values were marginal in terms of the NRC requirement of 0.80% K for a lactating beef cow, in 1977 the check plot forage had a K concentration of 0.86% and forage fertilized with 29 kg of P and

0 kg of K/ha had 0.84% K. The third value was associated with the tall fescue fertilized with N only in 1980 and had a K concentration of 0.83%.

Fall Forage Potassium Concentration

The K concentrations for fall harvested tall fescue in 1975 and 1977 are presented in Table 8. The main effects (P and K) were significant, but no PK interactions for the K concentration occurred. Both P and K had a significant effect on the K concentration of tall fescue in 1975. Phosphorus fertilization increased K concentration from 1.25% at the 0 kg rate to 1.41% at the 29 kg/ha rate. Potassium fertilization increased the K concentration from 1.20% at the 0 kg rate to 1.66% at the 112 kg/ha rate.

In 1977 the K concentration of fall harvested tall fescue was affected only by K fertilization. The K concentration was increased by the 112 kg/ha rate of K with the 28 kg/ha rate of K having no effect.

Potassium concentrations of fall harvested tall fescue were well above the NRC requirement of 0.60% K for a dry, pregnant beef cow in 1975 and 1977 with the exception of the check plot forage in 1977 which had a K concentration of 0.28% (National Research Council, 1976). Most of the values in both years were well above the 0.80% K NRC requirement for a lactating beef cow. There were three marginal values in terms of meeting the 0.80% K NRC requirement for a lactating beef cow. In 1975 the check plot forage had a K concentration of 0.87% and in 1977 marginal values were associated with forage fertilized with 0 kg of P and 28 kg of K/ha and forage fertilized with 29 kg of P and 0 kg of K/ha. Three values for K concentration were found to be deficient in meeting the 0.80% K NRC requirement for a lactating beef cow, the fescue

Table 8. Potassium concentration of tall fescue harvested in December averaged over four replications.

Fertilizer			Year	
N	P	K	1975	1977
kg/ha			%	
0	0	0	0.87	0.28
112	0	0	1.13	0.72
112	0	28	1.19	0.86
112	0	112	1.44	1.09
112	15	0	1.26	0.76
112	15	28	1.30	1.06
112	15	112	1.75	1.31
112	29	0	1.21	0.88
112	29	28	1.24	0.96
112	29	112	1.79	1.71
LSD	.05		0.21	0.40
Phosphorus Mean				
	0		1.25	0.89
	15		1.43	1.04
	29		1.41	1.18
LSD	.05		0.12	NS
Potassium Mean				
		0	1.20	0.78
		28	1.24	0.96
		112	1.66	1.37
LSD	.05		0.12	0.25

fertilized with 0 kg of P or 15 kg of P and 0 kg of K/ha.

Native Grass - Yield

The effects of fertilization on native grass forage production and chemical composition were not the main objectives of this study. Timing of the fertilizer applications was designed to enhance only the tall fescue production and may have caused increased competition by the fescue growth.

Dry matter yields of the native grass varied from 770 kg/ha to 5293 kg/ha during the course of the study (Table 9). Of the five years of production data obtained, only two years, 1977 and 1979, had significant treatment effects. The other three years of native grass production, 1975, 1976, and 1978 had no treatment effects and no main effects (P and K).

A significant PK interaction was observed in 1977. Native grass production associated with 15 kg of P and 28 kg of K/ha were significantly lower than the yields of any other PK combination used in the study. Yields of all other PK combinations were not different.

In 1979 native grass yields were reduced by P fertilization, but earlier that year the spring tall fescue production had been increased by P fertilization. Yields were reduced from 4989 kg/ha at the 0 kg rate to 4444 kg/ha at the 29 kg/ha rate. Yields were not significantly different due to the main effects of K. Production data in the six year mean were not significantly affected by any treatment combinations.

Table 9. Forage production of native grass harvested in mid August averaged over four replications.

Fertilizer			Year					5 Year
N	P	K	1975	1976	1977	1978	1979	Mean
kg/ha								
0	0	0	1827	2214	1602	2738	3657	2408
112	0	0	1890	2114	1228	2909	4856	2600
112	0	28	1594	2147	1358	3153	5293	2709
112	0	112	2285	2181	1240	2435	4818	2592
112	15	0	1590	2222	1311	2832	4592	2509
112	15	28	2104	2088	770	2433	3954	2270
112	15	112	2273	2470	1252	2683	4759	2687
112	29	0	2169	2063	1169	3094	4464	2592
112	29	28	1854	2291	1142	2744	4330	2472
112	29	112	2293	2289	1187	3017	4539	2665
LSD .05			NS	NS	330	NS	814	NS
Phosphorus Mean								
	0		1923	2147	1275	2832	4989	2633
	15		1989	2260	1111	2649	4435	2489
	29		2105	2214	1166	2952	4444	2576
LSD .05			NS	NS	NS	NS	487	NS
Potassium Mean								
		0	1883	2133	1236	2945	4637	2567
		28	1851	2175	1090	2777	4526	2484
		112	2284	2313	1226	2712	4705	2648
LSD .05			NS	NS	NS	NS	NS	NS

Native Grass - Nutrient Concentration

Nitrogen Concentration

The N concentration of native grass for 1975 through 1979 are presented in Table 10. There were neither significant PK interactions nor main effects (P and K) found in any year of the study or the six year mean. Nitrogen concentrations of native grass in 1979 were significantly affected by some treatment combinations. The lowest N concentration in 1979 (0.88%) was associated with native grass from the check plot and the highest N concentration (1.21%) was found to be from plots fertilized with the highest rates of P and K, 29 kg and 112 kg/ha respectively.

The N concentrations of native grass were all below the 1.47% N recommended by the NRC for a lactating beef cow (National Research Council, 1976). All values observed were above the 0.94% NRC requirement for a dry, pregnant beef cow with the exception of one observation in 1979 associated with the forage of the check plot which had a N concentration of 0.88%.

Phosphorus Concentration

Phosphorus concentrations of native grass for 1975 through 1979 are presented in Table 11. The main effects of P significantly affected P concentration in 1975, 1976, 1978, 1979, and in the five year mean. No main effects of K occurred in any year. A significant PK interaction was found only in 1977.

The first two years of the study (1975 and 1976) P concentration was increased by the 29 kg/ha rate of P. Phosphorus concentrations

Table 10. Nitrogen concentration of native grass harvested in mid August averaged over four replications.

Fertilizer			Year					5 Year
N	P	K	1975	1976	1977	1978	1979	Mean
kg/ha			%					
0	0	0	1.15	1.05	1.08	1.02	0.88	1.03
112	0	0	1.05	1.19	1.15	1.19	1.12	1.14
112	0	28	1.09	1.14	1.04	1.04	1.03	1.07
112	0	112	1.30	1.20	1.18	1.25	0.99	1.08
112	15	0	1.09	1.13	1.05	1.16	1.12	1.11
112	15	28	1.10	1.27	1.16	1.24	1.13	1.18
112	15	112	1.11	1.25	1.09	1.15	1.04	1.13
112	29	0	1.12	1.13	1.17	1.18	1.10	1.14
112	29	28	1.13	1.07	1.08	1.11	1.13	1.10
112	29	112	1.12	1.20	1.23	1.15	1.21	1.18
LSD .05			NS	NS	NS	NS	0.16	NS
Phosphorus Mean								
	0		1.15	1.17	1.12	1.16	1.04	1.13
	15		1.10	1.21	1.10	1.18	1.09	1.14
	29		1.12	1.13	1.16	1.14	1.15	1.14
LSD. 05			NS	NS	NS	NS	NS	NS
Potassium Mean								
		0	1.09	1.15	1.13	1.18	1.11	1.13
		28	1.11	1.16	1.09	1.13	1.09	1.12
		112	1.18	1.22	1.17	1.18	1.08	1.16
LSD .05			NS	NS	NS	NS	NS	NS

Table 11. Phosphorus concentration of native grass harvested in mid August averaged over four replications.

Fertilizer			Year					5 Year
N	P	K	1975	1976	1977	1978	1979	Mean
kg/ha			%					
0	0	0	0.13	0.09	0.11	0.15	0.10	0.12
112	0	0	0.12	0.10	0.08	0.09	0.13	0.10
112	0	28	0.12	0.09	0.08	0.10	0.09	0.09
112	0	112	0.13	0.10	0.11	0.11	0.11	0.11
112	15	0	0.15	0.12	0.13	0.16	0.16	0.14
112	15	28	0.13	0.11	0.13	0.16	0.16	0.14
112	15	112	0.14	0.11	0.14	0.16	0.18	0.14
112	29	0	0.15	0.12	0.17	0.20	0.18	0.16
112	29	28	0.16	0.16	0.16	0.22	0.21	0.18
112	29	112	0.14	0.14	0.15	0.20	0.22	0.17
LSD	.05		NS	0.03	0.02	0.04	0.04	0.02
Phosphorus Mean								
	0		0.12	0.10	0.09	0.10	0.11	0.10
	15		0.14	0.11	0.13	0.16	0.17	0.14
	29		0.15	0.14	0.16	0.20	0.20	0.17
LSD	.05		0.02	0.02	0.01	0.02	0.03	0.01
Potassium Mean								
		0	0.14	0.11	0.13	0.15	0.16	0.14
		28	0.13	0.12	0.12	0.16	0.15	0.14
		112	0.13	0.12	0.13	0.16	0.17	0.14
LSD	.05		NS	NS	NS	NS	NS	NS

associated with the forage fertilized with 0 kg or 15 kg/ha rate of P were not different.

In 1977 a significant PK interaction occurred when K fertilization increased P concentration at the low levels of P fertilization, but not at the high level of P fertilization. In 1978 P fertilization increased the P concentration of native grass with each additional P increment producing a significant increase in P concentration. The last year of the study (1979) P fertilization increased the P concentration from 0.11% at the 0 kg rate to 0.20% at the 29 kg/ha rate. Phosphorus concentrations were not different for the 15 kg or 29 kg/ha rate of P fertilization. The five year mean of P concentration was significantly increased by P fertilization, with each additional P increment producing an increase in P concentration.

Most of the observed values were below the NRC requirement of 0.18% P for a dry pregnant beef cow (National Research Council, 1976). All values were below the NRC requirement of 0.29% for a lactating beef cow.

Potassium Concentration

Potassium concentrations of native grass for 1975 through 1980 are presented in Table 12. There were no significant PK interactions found for K concentration of native grass in any year; therefore, main effects (P and K) will be discussed.

In the first two years of the study the effects of P and K fertilization on the K concentration of native grass were somewhat inconsistent. Potassium fertilization increased the K concentration of the native grass from 1.09% at the 0 kg rate to 1.18% at the 112 kg/ha rate in 1975 and no effects of P fertilization were seen. In 1976 P

Table 12. Potassium concentration of native grass harvested in mid August averaged over four replications.

Fertilizer			Year					5 Year
N	P	K	1975	1976	1977	1978	1979	Mean
kg/ha			%					
0	0	0	0.97	0.77	0.62	0.84	0.80	0.80
112	0	0	0.94	0.82	0.51	0.70	0.98	0.79
112	0	28	0.99	0.78	0.55	0.82	0.81	0.79
112	0	112	1.45	0.85	0.72	1.40	1.41	1.17
112	15	0	0.84	0.90	0.52	0.79	0.94	0.80
112	15	28	1.10	0.99	0.59	0.93	1.02	0.92
112	15	112	1.22	0.98	0.71	1.15	1.42	1.09
112	29	0	1.05	0.89	0.57	0.88	0.78	0.83
112	29	28	1.00	0.87	0.52	0.90	0.95	0.85
112	29	112	1.10	1.02	0.71	1.21	1.47	1.10
LSD	.05		0.24	0.17	NS	0.25	0.21	0.09
Phosphorus Mean								
	0		1.12	0.82	0.60	0.97	1.07	0.91
	15		1.05	0.95	0.61	0.95	1.13	0.94
	29		1.05	0.93	0.60	1.00	1.07	0.93
LSD	.05		NS	0.10	NS	NS	NS	NS
Potassium Mean								
		0	0.94	0.87	0.53	0.79	0.90	0.81
		28	1.02	0.88	0.55	0.88	0.93	0.85
		112	1.26	0.95	0.71	1.25	1.43	1.12
LSD	.05		0.14	NS	0.09	0.15	0.12	0.06

fertilization increased the K concentration of the native grass from 0.82% at the 0 kg rate to 0.93% at the 29 kg/ha rate but no K effects were noted.

In the last three years of the study (1977 through 1979) the K concentration of the native grass was increased by K fertilization. In all three years the K concentration of the native grass was significantly increased by the 112 kg/ha rate of applied K above that K concentration observed from native grass receiving either 0 kg or 28 kg/ha rates of K. The K concentrations of native grass receiving the 0 kg or 28 kg/ha rates of K were not significantly different.

These same results were observed in the five year mean. Phosphorus fertilization had no effect on the K concentration of the forage in the last three years or in the first five year mean.

All observed values were above the NRC requirement of 0.60% K (National Research Council, 1976) for a dry, pregnant beef cow with the exception of the native grass fertilized with 0 kg of K or 28 kg of K/ha at all three rates of P (0, 15, and 29 kg/ha) in 1977. Most of the observed values associated with the highest rate of applied K (112 kg/ha) were above the 0.80% K NRC requirement for a lactating beef cow.

Soil

The Wynona silty clay loam soil of the study is a loamy bottomland range site. It consists of deep, nearly level soils on flood plains which are somewhat poorly drained, have slow permeability and have a high available water capacity. These soils developed from loamy sediments under a cover of trees with an understory of grasses. It is used mainly for rangeland and tame pastures.

Soil samples were taken before treatments were applied in February of 1975. Soil P values ranged from 10 kg/ha to 14 kg/ha with no significant difference in plots (Table 13). The following May, after treatments were applied, significant increases of soil P were found due to P fertilization. Each increment of P fertilizer increased soil P and this trend continued to the end of the study. By 1980 the highest rate of applied P (29 kg/ha) had a soil P value of 60 which is approximately 83% sufficient for maximum yields of tall fescue (Tucker, 1977). The K fertilization had no effect on soil P and there was never a PK interaction. Available soil P values for the 15-30 cm depth for 1975 and 1980 are presented in Table 14. Soil P values at the 15-30 cm depth were not affected by any fertility treatment.

In 1975 before fertilizer treatment application, soil K values for the 0-15 cm depth ranged from 210 kg/ha to 230 kg/ha but no significant differences were noted (Table 15). The effect of fertilizer K in increasing soil K was apparent by May, 1975, and remained rather constant throughout the study. By 1980, the soil K had been reduced by the use of P fertilizer. This may be a result of greater forage production attributed to the P fertilization. No PK interactions were observed. The highest rate of applied K (112 kg/ha) had a soil K value of 283, and this level of K is 100% sufficient for maximum tall fescue yields (Tucker, 1977).

Available soil K values for the 15-30 cm depth were affected by K fertilization (Table 16). In 1975, before treatments were applied, soil K values at the 15-30 cm depth were not significantly different. The differences noted in 1980 may not be a result of a downward movement of K from the K fertilized treatment. Instead, it appears that more soil K

Table 13. Available soil phosphorus, 0-15 cm depth averaged over four replications.

Fertilizer			1975		1976	1977	1978	1979	1980
N	P	K	Feb.	May	July	Aug.	May	May	Nov.
kg/ha									
0	0	0	14	15	16	13	20	22	26
112	0	0	12	15	15	11	19	18	20
112	0	28	10	13	14	10	18	17	23
112	0	112	12	14	14	12	20	36	23
112	15	0	10	21	20	24	21	30	35
112	15	28	10	19	21	24	24	29	33
112	15	112	10	18	18	29	24	31	31
112	29	0	10	21	27	53	45	59	59
112	29	28	12	25	30	43	44	72	57
112	29	112	10	25	36	53	44	65	64
LSD	.05		NS	5	7	14	6	23	14
Phosphorus Mean									
	0		11	14	14	11	19	24	22
	15		10	19	20	26	23	30	33
	29		11	24	31	50	44	65	60
LSD	.05		NS	3	4	8	4	14	8
Potassium Mean									
		0	11	19	21	29	28	36	38
		28	11	19	22	26	29	39	38
		112	11	19	23	31	29	44	39
LSD	.05		NS	NS	NS	NS	NS	NS	NS

Table 14. Available soil phosphorus, 15-30 cm depth averaged over four replications.

Fertilizer			1975	1980
N	P	K	Feb.	Nov.
kg/ha				
0	0	0	7	15
112	0	0	7	14
112	0	28	7	18
112	0	112	8	16
112	15	0	7	16
112	15	28	7	17
112	15	112	7	16
112	29	0	7	16
112	29	28	6	18
112	29	112	7	17
LSD .05			NS	NS
Phosphorus Mean				
	0		7	16
	15		7	16
	29		7	17
LSD .05			NS	NS
Potassium Mean				
		0	7	15
		28	7	18
		112	7	17
LSD .05			NS	NS

Table 15. Available soil potassium, 0-15 cm depth averaged over four replications.

Fertilizer			1975		1976	1977	1978	1979	1980
N	P	K	Feb.	May	July	Aug.	May	May	Nov.
kg/ha									
0	0	0	224	213	227	206	223	246	185
112	0	0	224	232	231	192	203	228	190
112	0	28	216	220	224	202	207	239	223
112	0	112	230	272	273	263	281	285	304
112	15	0	216	203	216	176	206	220	166
112	15	28	218	227	238	199	211	218	219
112	15	112	221	260	270	246	263	304	268
112	29	0	213	217	211	188	199	246	165
112	29	28	216	216	227	197	198	219	204
112	29	112	210	266	266	247	250	294	276
LSD	.05		NS	23	22	28	28	36	22
Phosphorus Mean									
	0		223	241	243	219	230	251	239
	15		218	230	241	207	227	247	217
	29		213	233	235	211	216	253	215
LSD	.05		NS	NS	NS	NS	NS	NS	13
Potassium Mean									
		0	217	217	219	186	202	232	174
		28	217	221	230	199	205	225	216
		112	220	266	270	252	265	294	283
LSD	.05		NS	14	13	17	17	21	13

Table 16. Available soil potassium, 15-30 cm depth averaged over four replications.

Fertilizer			1975	1980
N	P	K	Feb.	Nov.
			kg/ha	
0	0	0	230	188
112	0	0	258	198
112	0	28	238	206
112	0	112	241	207
112	15	0	230	166
112	15	28	238	203
112	15	112	249	220
112	29	0	238	164
112	29	28	238	195
112	29	112	238	211
LSD	.05		NS	27
Phosphorus Mean				
	0		245	204
	15		239	196
	29		238	190
LSD	.05		NS	NS
Potassium Mean				
		0	242	176
		28	238	201
		112	243	213
LSD	.05		NS	15

was being removed from the subsoil by forage on the treatments receiving no K fertilizer. The soil K in the subsoil was not affected by P fertilizer and no PK interactions were noted.

Soil pH values of the 0-15 cm depth (Table 17) and the 15-30 cm depth (Table 18) were not significantly affected by fertility treatments.

Table 17. Soil pH, 0-15 cm depth averaged over four replications.

Fertilizer			1975		1976	1977	1978	1979	1980
N	P	K	Feb.	May	July	Aug.	May	May	Nov.
— kg/ha —									
0	0	0	5.6	5.7	5.9	6.0	5.5	5.7	5.7
112	0	0	5.7	5.7	5.9	5.9	5.5	5.6	5.7
112	0	28	5.7	5.7	5.9	5.9	5.4	5.6	5.5
112	0	112	5.4	5.6	5.8	5.8	5.4	5.5	5.5
112	15	0	5.6	5.8	6.0	6.0	5.5	5.7	5.7
112	15	28	5.7	5.6	5.9	5.9	5.4	5.6	5.5
112	15	112	5.8	5.7	5.9	5.9	5.5	5.6	5.5
112	29	0	5.6	5.6	5.8	5.9	5.5	5.6	5.7
112	29	28	5.7	5.7	5.9	5.9	5.5	5.6	5.6
112	29	112	5.7	5.7	5.8	5.9	5.5	5.7	5.6
LSD .05			NS	NS	NS	NS	NS	NS	NS
Phosphorus Mean									
	0		5.6	5.7	5.9	5.9	5.4	5.6	5.6
	15		5.7	5.7	5.9	5.9	5.5	5.6	5.6
	29		5.6	5.7	5.9	5.9	5.5	5.6	5.6
LSD .05			NS	NS	NS	NS	NS	NS	NS
Potassium Mean									
		0	5.6	5.7	5.9	5.9	5.5	5.6	5.7
		28	5.7	5.7	5.9	5.9	5.4	5.6	5.6
		112	5.6	5.6	5.8	5.9	5.4	5.6	5.5
LSD .05			NS	NS	NS	NS	NS	NS	NS

Table 18. Soil pH, 15-30 cm depth averaged over four replications.

Fertilizer			1975	1980
N	P	K	Feb.	Nov.
— kg/ha —				
0	0	0	5.5	5.8
112	0	0	5.6	5.7
112	0	28	5.6	5.7
112	0	112	5.6	5.7
112	15	0	5.7	5.7
112	15	28	5.5	5.4
112	15	112	5.5	5.6
112	29	0	5.6	5.6
112	29	28	5.6	5.7
112	29	112	5.5	5.6
LSD	.05		NS	NS
Phosphorus Mean				
	0		5.6	5.7
	15		5.6	5.6
	29		5.6	5.6
LSD	.05		NS	NS
Potassium Mean				
		0	5.6	5.6
		28	5.5	5.6
		112	5.5	5.6
LSD	.05		NS	NS

CHAPTER V

SUMMARY AND CONCLUSIONS

This investigation consisted of a native hay meadow overseeded with tall fescue fertilized with concentrated superphosphate at 0, 15, and 29 kg of P/ha and muriate of potash at 0, 28, and 112 kg of K/ha. The purpose of the study was to investigate the effects of fertilizer P and K on certain agronomic characteristics, specifically forage production of the area and the subsequent forage mineral composition in terms of percent N, P, and K and soil test values for pH, P, and K.

Phosphorus fertilization increased spring yields of tall fescue starting the second year (1976) of the study and increased yields each year subsequently. Forage production was increased by K fertilization in only two years of the study (1977 and 1978). The N concentration of spring harvested tall fescue was depressed by P fertilization possibly due to a dilution factor from the greater forage production realized from P fertilization. This depressing effect was found to be significant in three years of the study (1977, 1978, and 1980). In each of these years the 15 kg and 29 kg/ha rates of P significantly depressed the N concentration of spring tall fescue below that observed of fescue fertilized with the 0 kg/ha rate of P. Forage P concentration of spring tall fescue was increased by P fertilization each year of the study. Generally each increment of P fertilizer produced an increase in P concentration of the tall fescue. The P concentration was increased by K

fertilization in only one year (1978). The K concentration of spring fescue was increased each year by K fertilization. A significant PK interaction occurred in 1978 for K concentration of spring tall fescue, otherwise the K concentration of fescue was not affected by P fertilization.

Fall forage production of tall fescue was a variable forage source. Only in two years (1975 and 1977) was there sufficient forage to harvest. It seemed that September soil moisture appeared to be a critical factor for this fall growth of tall fescue. Normal precipitation for September is 10 cm and this was exceeded only in 1977. Fall forage production of tall fescue in 1975 was not significantly affected by P or K fertilization. In 1977 yields of fall harvested tall fescue was increased by P but not by K fertilization. The N concentration of fall tall fescue was decreased by P fertilization in 1975 but no response was found in 1977. The forage N concentration was not influenced by K fertilization. Phosphorus concentration of fall harvested tall fescue was increased by P fertilization in both 1975 and 1977. Potassium fertilization had no effect on P concentration in either year. Potassium concentration of fall harvested tall fescue was increased by K fertilization in both 1975 and 1977. In 1975 P fertilization of fescue increased the K concentration but this effect was not seen in 1977.

Forage production of native grass was somewhat erratic. Of the five years of production data obtained, only two years (1977 and 1978), were found to have significant differences due to treatment combinations. In 1977 a significant PK interaction was found for native grass forage production. Forage production was reduced by P fertilization in 1979. Variable effects of fertilizer treatments for production may be a

sign that the tall fescue production had utilized most of the N applied. The efficiency with which forages utilize a nutrient depends upon adequate availability of the other nutrients necessary for growth and good production. The native grass N concentration was found to be affected by treatment combinations only in 1979. No other effects were found in any year. Native grass P concentration was increased by P fertilization each year. In 1977 a significant PK interaction was noted, otherwise K fertilization did not influence P concentration. The K concentration of the native grass was increased each year by K fertilization and P fertilization had no effect with the exception of 1976. In 1976 P fertilization increased the K concentration but K fertilization had no effect.

The botanical composition of the area was taken on 3 October 1980 and was not significantly different due to fertility treatments. The four major decreaser species, big bluestem (Andropogon gerardi), little bluestem (Schizachyrium scoparius), indiangrass (Sorghastrum nutans), and switchgrass (Panicum virgatum) comprised 65% of the total vegetation. This indicated that the native hay meadow was kept in good condition.

Available soil P at the 0-15 cm depth was increased each year by P fertilization but not by K fertilization. Soil P at the 15-30 cm was not influenced by P fertilization in either 1975 or 1980.

Available soil K at the 0-15 cm depth was increased each year by K fertilization and in 1980 P fertilization decreased the soil K. Since P fertilization increased forage production plants were more efficient in removing K from the soil and this lead to a reduction. Available soil K values at the 15-30 cm depth were not significantly different before treatments were applied in 1975. However, in 1980, K fertilization

increased soil K at the 15-30 cm depth. Soil pH at the 0-15 cm and the 15-30 cm depths were not influenced by P or K fertilization.

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Table 19. Monthly precipitation received at Pawhuska, Oklahoma (10 miles north of study area). Source: U.S. Dept. of Commerce. 1975-1980. Climatological Data.

Month	Year						Long Term Mean
	1975	1976	1977	1978	1979	1980	
	cm						
January	8.61	T	1.24	2.54	7.21	4.34	3.20
February	5.97	2.26	5.46	6.45	2.08	3.63	3.68
March	8.74	7.34	5.13	5.33	7.21	9.88	5.74
April	4.72	12.80	4.83	8.74	9.53	10.64	8.61
May	23.65	10.21	22.61	16.08	9.17	10.29	13.59
June	14.86	9.47	4.57	8.10	14.94	11.68	11.23
July	3.38	13.74	6.12	8.46	12.12	T	7.77
August	11.91	2.95	16.97	6.81	12.19	5.87	7.92
September	7.26	5.33	16.69	1.78	2.29	4.95	9.96
October	3.53	7.85	4.27	0.41	5.89	7.01	7.75
November	3.81	0.15	7.06	10.52	15.44	2.06	5.03
December	2.69	0.43	0.79	2.11	2.01	4.04	3.51
Total	99.13	72.53	95.74	77.33	100.08	74.39	87.99
Departure	11.14	-15.46	7.75	-10.66	12.09	-13.60	

Table 20. Botanical composition of the study area, mean of all plots, taken 3 October 1980.

Scientific Name	Common Name	Percent of Total Plants
<u>Andropogon gerardi</u>	Big bluestem	27.4
<u>Panicum virgatum</u>	Switchgrass	1.0
<u>Schizachyrium scoparius</u>	Little bluestem	9.6
<u>Sorghastrum nutans</u>	Indiangrass	27.2
Sub Total of Decreasers		65.2
<u>Andropogon saccharoides</u>	Silver bluestem	0.3
<u>Carex</u> spp.		0.8
<u>Eragrostis intermedia</u>	Plains lovegrass	1.3
<u>Eragrostis spectabilis</u>	Purple lovegrass	0.5
<u>Panicum scribnerianum</u>	Schribner's panicum	0.3
<u>Paspalum stramineum</u>	Sand paspalum	5.0
<u>Sporobolus asper</u>	Tall dropseed	0.5
<u>Tridens flavus</u>	Purpletop	2.5
Sub Total of Increasers		11.2
<u>Asistida obigantha</u>	Prairie threeawn	8.0
<u>Euphorbia supina</u>	Prostrate spurge	0.3
<u>Digitaria sanguinalis</u>	Crabgrass	3.0
<u>Solanum carolinense</u>	Carolina horsenettle	0.3
Sub Total of Invaders		11.6
<u>Cynodon dactylon</u>	Bermudagrass	6.0
<u>Festuca arundinacea</u>	Tall fescue	6.0
Sub Total of Exotics		12.0

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